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WIND-TUNNEL INVESTIGATION AT MACH NUMBERS FROM 0.20 TO 1.17

OF THE STATIC AERODYNAMIC CHARACTERISTICS OF

A POSSIBLE REENTRY CAPSULE

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CASE
FILE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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OF THE STATIC AERODYNAMIC CHARACTERISTICS OF
A POSSIBLE REENTRY CAPSULE*

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SUMMARY

The static pitching-moment, normal-force, and axial-force characteristics of exit, escape, and reentry configurations of a model of a possible reentry capsule were investigated in the Langley 8-foot transonic pressure tunnel. The tests were conducted at angles of attack from approximately -2° to 40° for the exit and reentry configurations and from about -2° to 20° for the escape configuration. The Reynolds number varied from about 0.57×10^6 to 3.69×10^6 .

The results show that all the models trimmed and had positive static stability at angles of attack near 0° . Pitchup occurred for the exit configuration near 3° , after which the model was statically unstable. The addition of the tower and escape rocket to the exit configuration tended to decrease the slope of the normal-force coefficient $C_{N_{\alpha}}$ and to affect the axial-force characteristics only at the lower angles of attack. The effects of Reynolds number on the static aerodynamic characteristics were negligible.

INTRODUCTION

A wind-tunnel research program was initiated by the National Aeronautics and Space Administration to investigate the static aerodynamic characteristics of models of blunt, nonlifting vehicles suitable for reentry. The results of some of these investigations at subsonic, transonic, or supersonic speeds are given in references 1 to 3.

*Title, Unclassified.

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The present investigation, performed in the Langley 8-foot transonic pressure tunnel, provides information at subsonic and transonic speeds on one of the model capsules of reference 3. The model was tested as a reentry configuration, with the blunt end facing the relative wind; as an exit configuration, with the small cylindrical end facing the relative wind; and as an escape configuration, the same as the exit configuration but with a tower and rocket tube attached to the cylindrical end. The investigation was performed at Mach numbers from 0.20 to 1.17 at angles of attack from about -2° to 40° . The Reynolds number, based on maximum body diameter, varied from about 0.57×10^6 to 3.69×10^6 .

SYMBOLS

The data presented herein are referred to the body system of axes with the origin located at the center-of-gravity position. The positive directions of forces, moments, and displacements are shown in figure 1. The coefficients and symbols are defined as follows:

C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qAd}$
C_{m_α}	slope of pitching-moment coefficient per degree at $\alpha \approx 0^\circ$, $\frac{\partial C_m}{\partial \alpha}$
$C_{p,c}$	model-balance chamber-pressure coefficient, $\frac{\text{Chamber pressure} - \text{Free-stream static pressure}}{q}$
C_N	normal-force coefficient, $\frac{\text{Normal force}}{qA}$
C_{N_α}	slope of normal-force coefficient per degree at $\alpha \approx 0^\circ$, $\frac{\partial C_N}{\partial \alpha}$
C_A	axial-force coefficient, $\frac{\text{Axial force}}{qA}$
M	free-stream Mach number
q	free-stream dynamic pressure, lb/sq ft
R	Reynolds number based on maximum body diameter and free-stream conditions
d	maximum body diameter, in.

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- A maximum cross-sectional area, sq ft
- α angle of attack of model center line, deg

MODELS, TESTS, AND ACCURACY

Details of the model configurations tested are shown in figure 2 and photographs are presented in figure 3. The capsule model used for the reentry configuration was a body of revolution made from plastic-impregnated fiber glass attached to a steel core. For this configuration, the large, blunt end faced the relative wind. The exit configuration consisted of the same capsule model but the small, cylindrical end faced the relative wind. The escape configuration was composed of a cylindrical aluminum-alloy body, simulating a rocket container, mounted on a tower made from three steel rods attached to the nose of the exit configuration. The two upper rods of the tower were in a horizontal plane.

The tests were conducted in the Langley 8-foot transonic pressure tunnel at Mach numbers from 0.20 to 1.17 at stagnation pressures of either 1.0 or 0.5 atmosphere and, at some Mach numbers, both pressures. The dewpoint temperature was such that the airflow was free of condensation shocks. The variation of Reynolds number, based on maximum body diameter, with Mach number is shown in figure 4. The model angle of attack, which was varied from about -2° to 40° for the exit and reentry configurations and from approximately -2° to 20° for the escape configuration, was determined by means of a calibrated, fixed-pendulum strain-gage unit located behind the model in the main sting support.

The models were mounted on a three-component strain-gage balance and were sting supported. An orifice was located inside the model in the strain-gage-balance chamber and the pressure in this chamber was determined by means of a calibrated pressure transducer. Normal force, axial force, and pitching moment were determined by means of the internal strain-gage balance with the pitching moments referred to the center of gravity. The axial-force results are gross values and have not been adjusted to a condition of free-stream static pressure at the model base. Based upon balance accuracy and repeatability of data, it is estimated that the coefficients of normal force, axial force, and pitching moment are accurate within ± 0.098 , ± 0.098 , and ± 0.020 , respectively, at a Mach number of 0.20, and within ± 0.006 , ± 0.006 , and ± 0.001 , respectively, at a Mach number of 1.17. All data presented from this investigation are essentially free of wall-reflected disturbances. The maximum variation of the actual test Mach numbers from the presented nominal values is less than ± 0.005 . Corrections were applied for tunnel flow angularity and for model sting and balance deflections. The accuracy of the angle of attack is estimated to be within $\pm 0.20^\circ$.

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RESULTS

Static Stability and Trim Characteristics

The three configurations tested have positive static stability near 0° angle of attack throughout the Mach number range of this investigation. (See figs. 5(a), 6(a), 7(a), and 8.) Pitchup, however, occurs for the exit configuration near an angle of attack of 3° , after which the model becomes unstable. The effects of Reynolds number are negligible on the static stability characteristics.

The data of figures 5(a), 6(a), and 7(a) also show that the three configurations trim at an angle of attack near 0° and that an unstable trim point exists for the exit configuration near angles of attack from about 5° to 10° (fig. 5(a)).

As stated in reference 1, it is necessary for the capsule (without the tower and escape rocket attached) to trim and have positive static stability only when the heat sink (blunt face) faces the relative wind. The present model does not meet this requirement, inasmuch as the exit configuration also trims and has positive static stability near 0° angle of attack.

Normal- and Axial-Force Characteristics

The normal-force characteristics are shown in figures 5(b), 6(b), and 7(b), and are summarized in figure 8. For the reentry configuration, the results are similar to those reported in reference 1; that is, the model had low values of C_{N_α} which were nearly zero or negative. Addition of the tower and escape rocket to the exit configuration tended to decrease C_{N_α} .

The axial-force coefficients for the reentry configuration (fig. 6(c)) are essentially constant with variation of angle of attack to about 20° . For the exit and escape configurations, however, the axial-force coefficients tended to reach a maximum at angles of attack from about 4° to 10° . (See figs. 5(c) and 7(c).) Addition of the tower and escape rocket to the exit configuration had a negligible effect on the axial-force coefficients at the higher angles of attack but reduced these coefficients at angles of attack near 0° . The effect of Reynolds number on the axial-force characteristics is negligible.

The variations of chamber-pressure coefficient with angle of attack are shown in figure 9 for the Mach numbers of this investigation.

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CONCLUDING REMARKS

The results of wind-tunnel tests of exit, escape, and reentry configurations of a possible reentry capsule, performed in the Langley 8-foot transonic pressure tunnel at Mach numbers from 0.20 to 1.17, indicate that all the models trimmed and had positive static stability at angles of attack near 0° . The exit configuration, therefore, may not be suitable as it should be unstable near 0° angle of attack. Pitchup, however, occurred for the exit model near an angle of attack of 3° , after which the model remained statically unstable. The addition of the tower and escape rocket to the exit configuration tended to decrease the slope of the normal-force coefficient C_{N_α} and to affect the axial-force characteristics only at the lower angles of attack. The effects of Reynolds number on the static aerodynamic characteristics of all configurations were negligible.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., December 4, 1959.

REFERENCES

1. Pearson, Albin O.: Wind-Tunnel Investigation at Mach Numbers From 0.40 to 1.14 of the Static Aerodynamic Characteristics of a Nonlifting Vehicle Suitable for Reentry. NASA MEMO 4-13-59L, 1959.
2. Turner, Kenneth L., and Shaw, David S.: Wind-Tunnel Investigation at Mach Numbers From 1.60 to 4.50 of the Static-Stability Characteristics of Two Nonlifting Vehicles Suitable for Reentry. NASA MEMO 3-2-59L, 1959.
3. Shaw, David S., and Turner, Kenneth L.: Wind-Tunnel Investigation of Static Aerodynamic Characteristics of a 1/9-Scale Model of a Possible Reentry Capsule at Mach Numbers From 2.29 to 4.65. NASA TM X-233, 1959.

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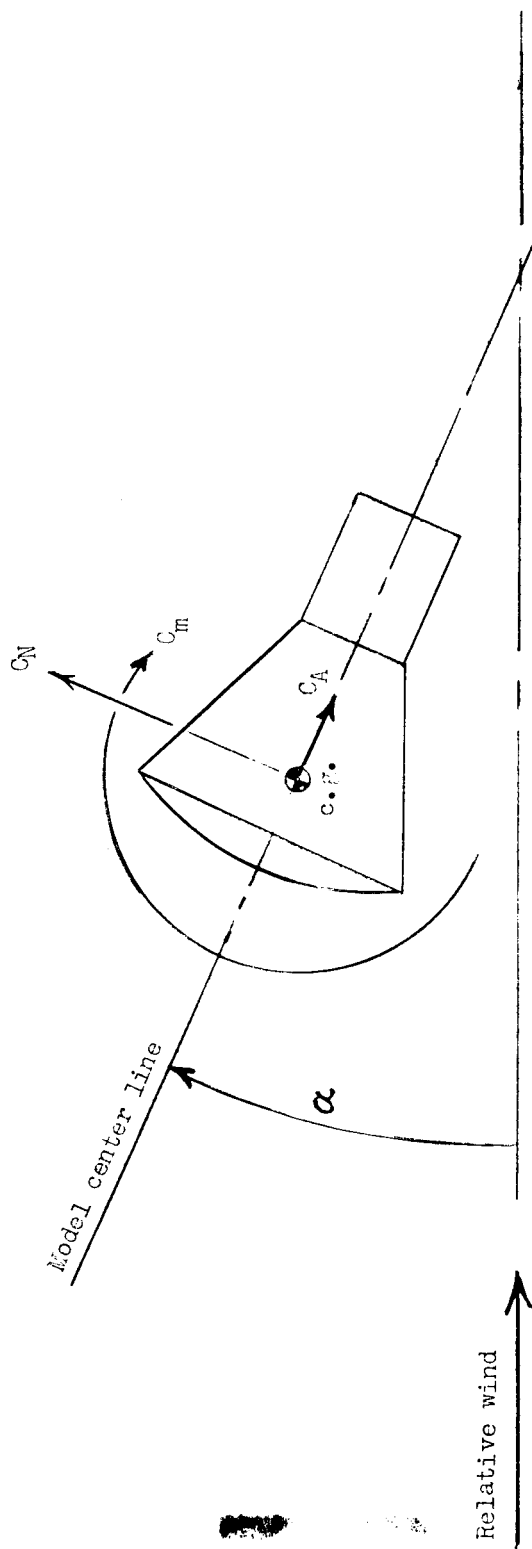
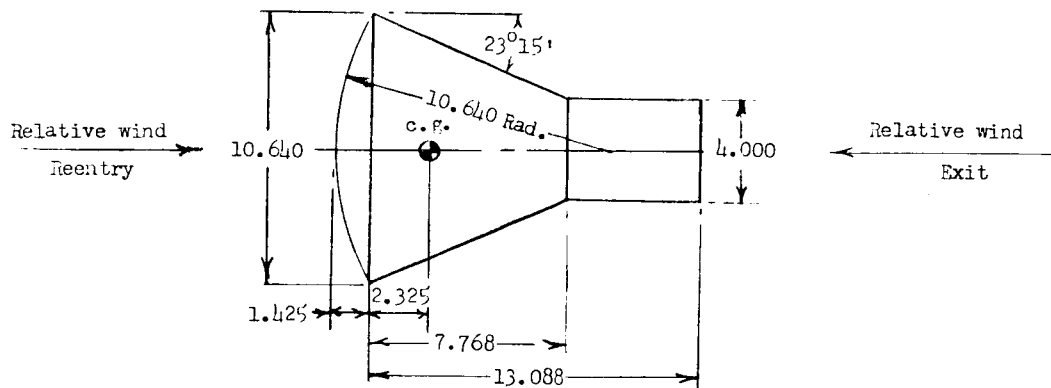


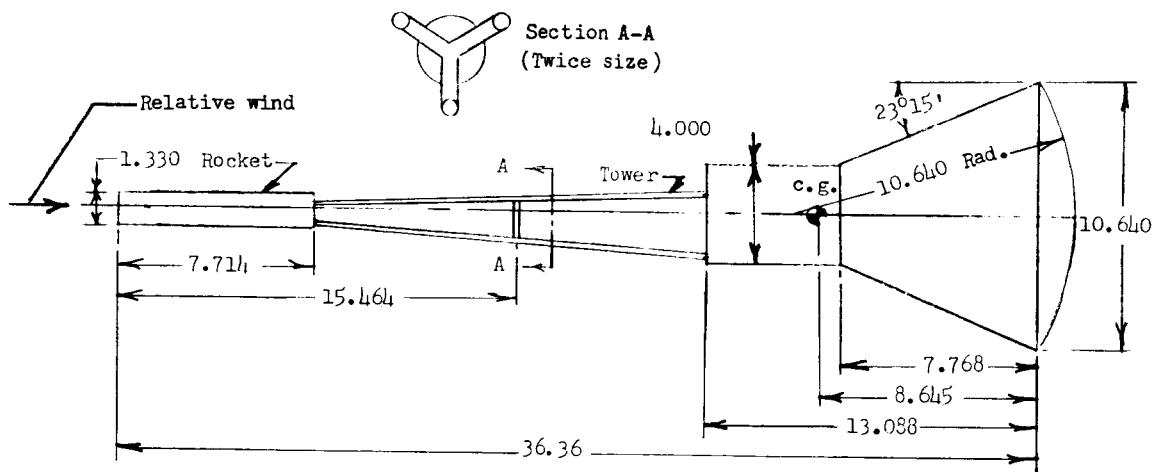
Figure 1.- Body-axis system. Arrows indicate positive directions.

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(a) Exit and reentry configurations.



(b) Escape configuration.

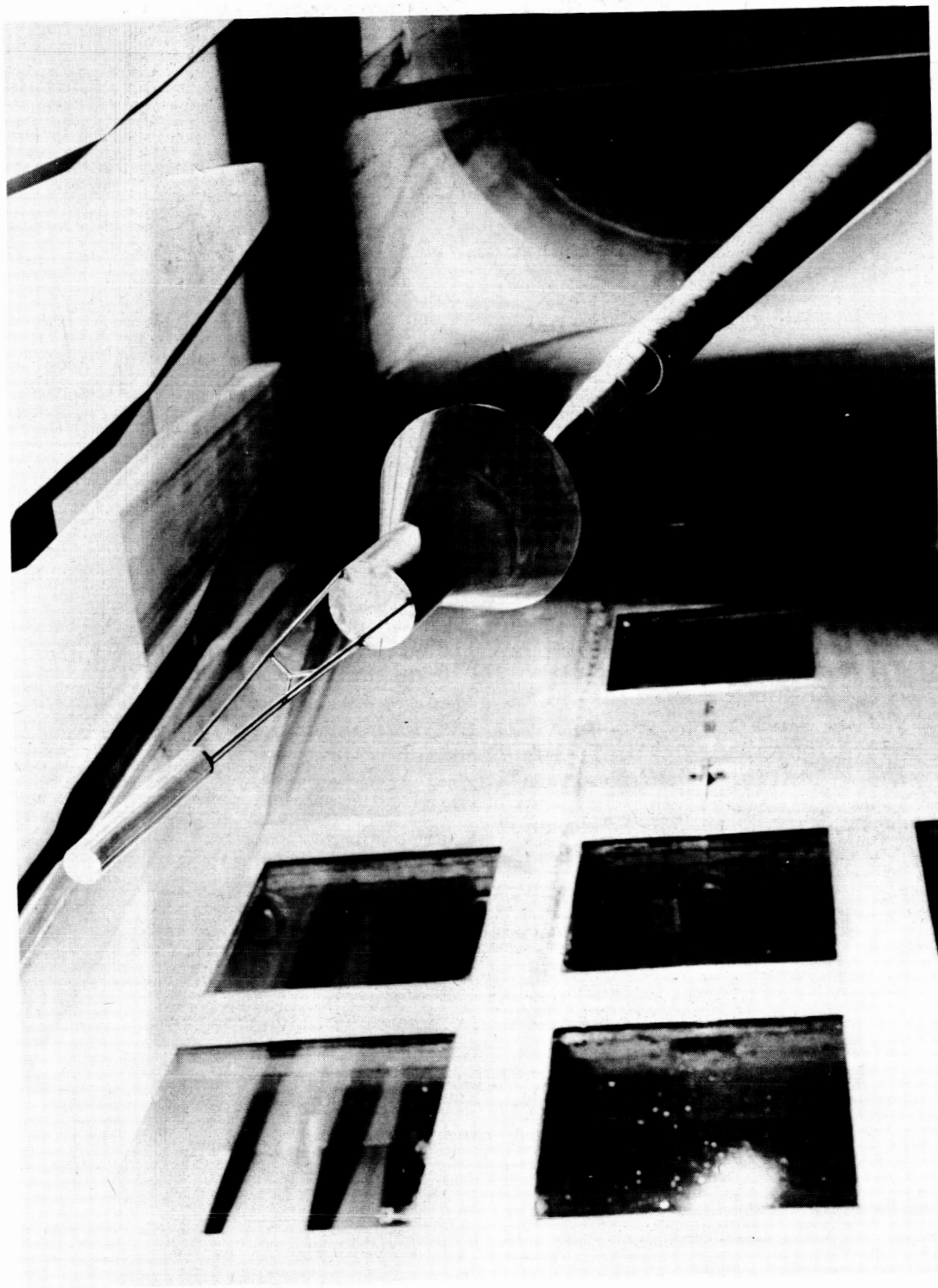
Figure 2.- Details of model configurations. All dimensions are in inches unless otherwise noted.



(a) Exit configuration.

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Figure 3.- Photographs of models.

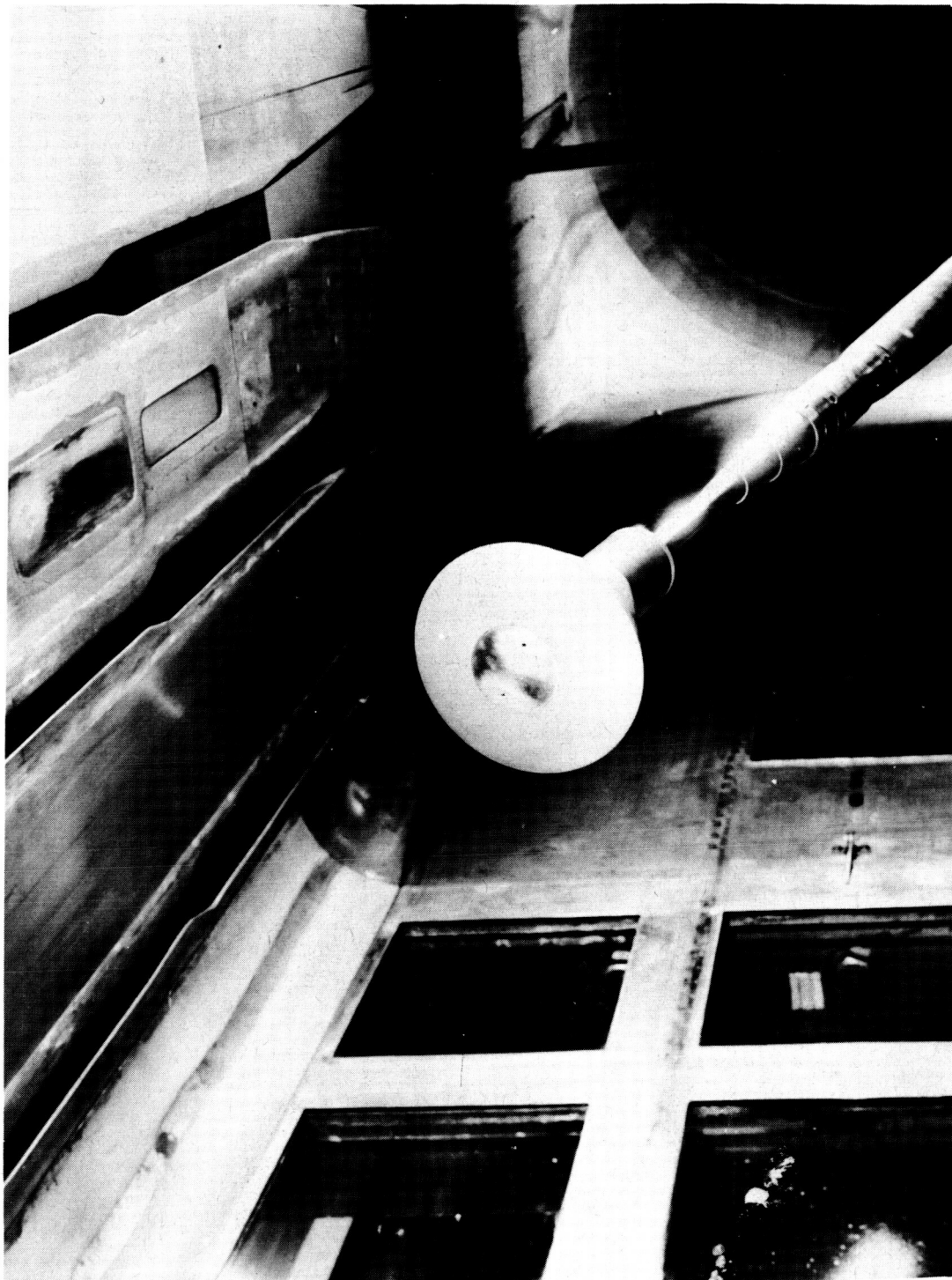


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(b) Escape configuration.

Figure 3.- Continued.

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(c) Reentry configuration.

Figure 3.- Concluded.

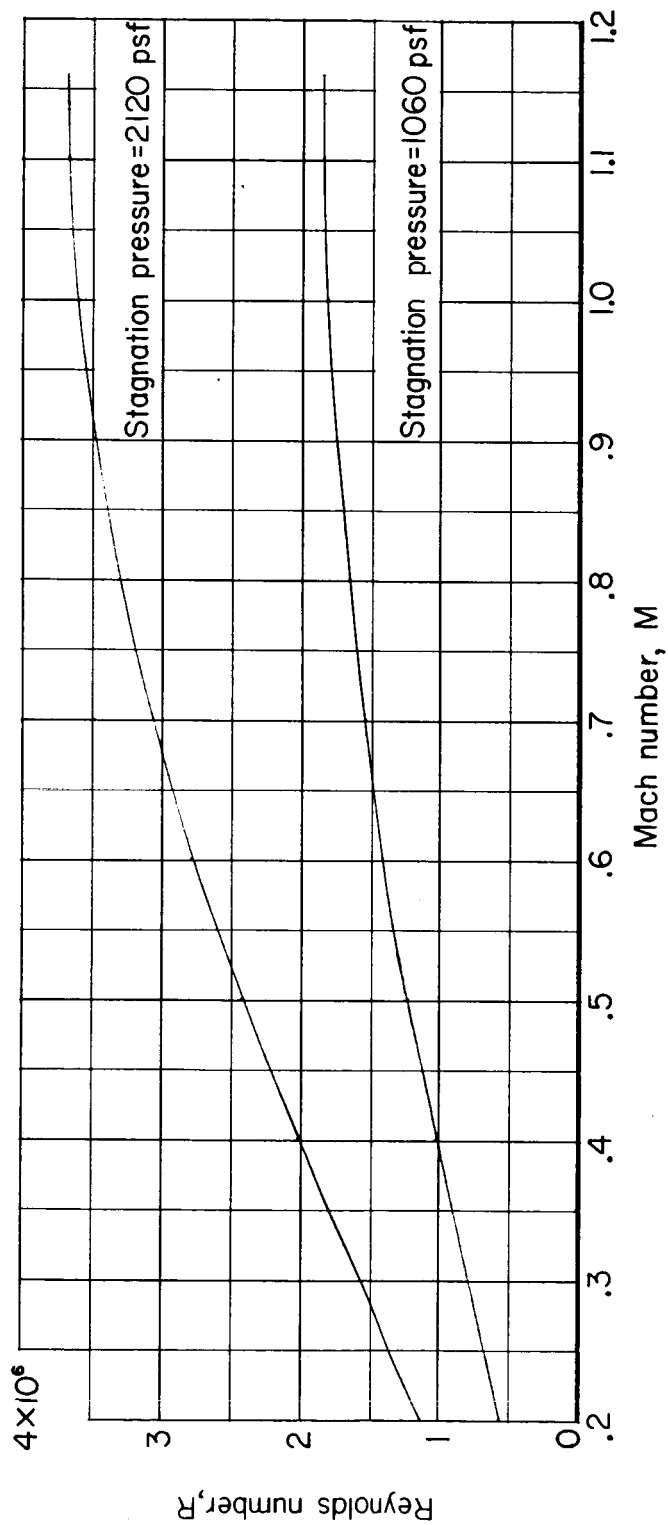


Figure 4.- Variation of test Reynolds number, based on maximum body diameter, with Mach number.

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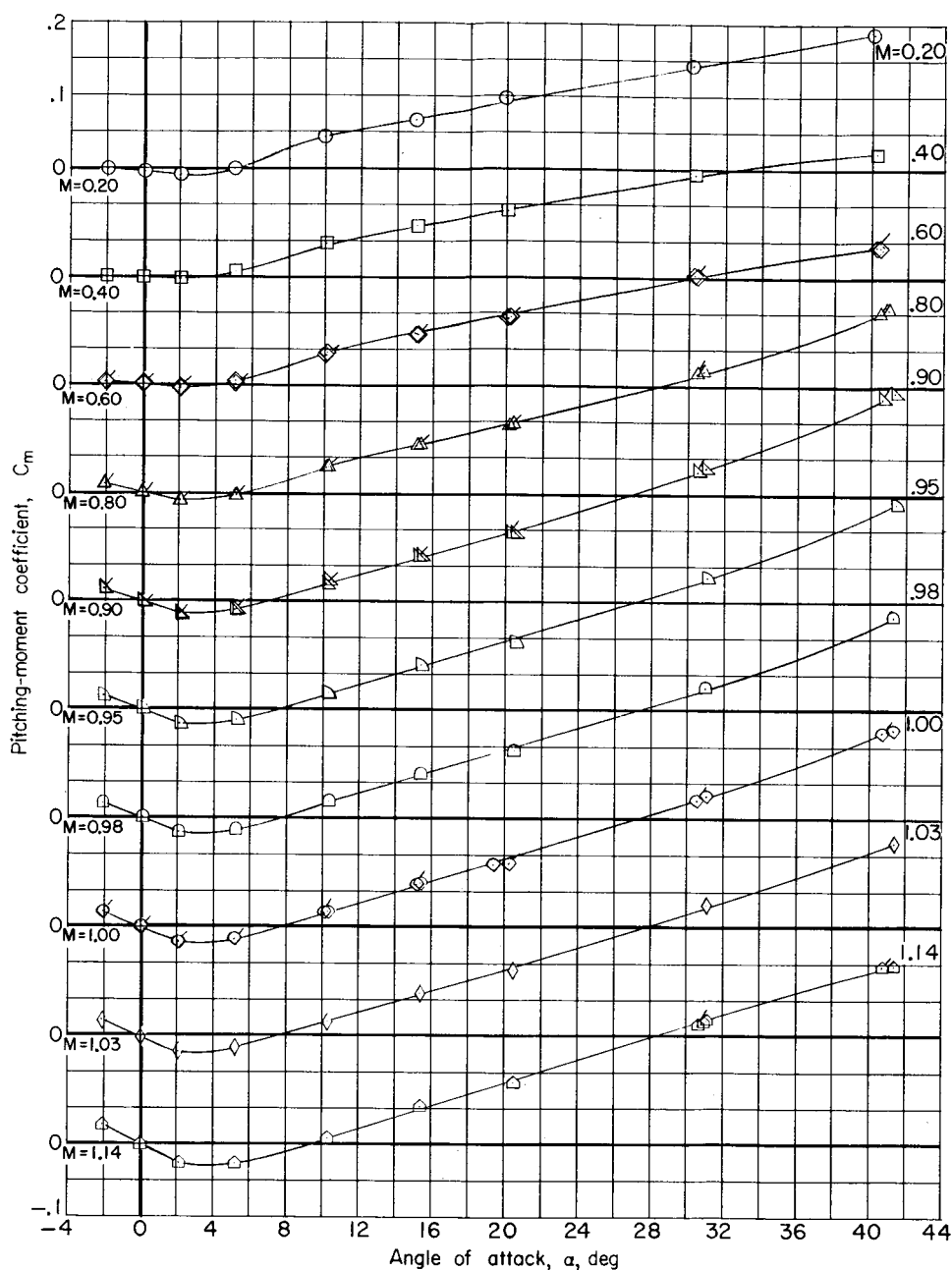
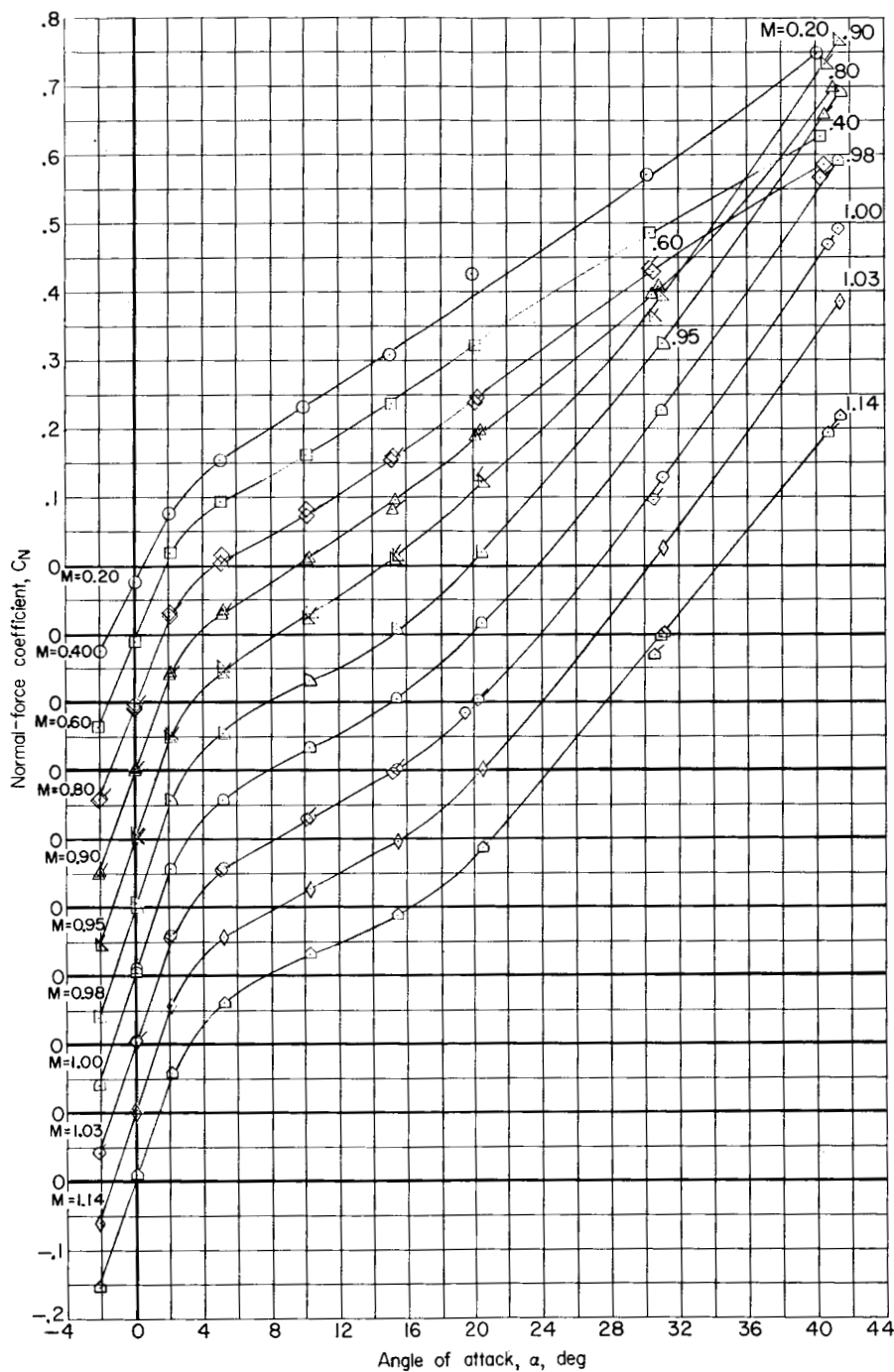


Figure 5.- Variation of static aerodynamic characteristics in pitch of model. Exit configuration. Unflagged symbols denote stagnation pressure of 1.0 atmosphere; flagged symbols denote stagnation pressure of 0.5 atmosphere.



(b) Variation of C_N with α .

Figure 5.- Continued.

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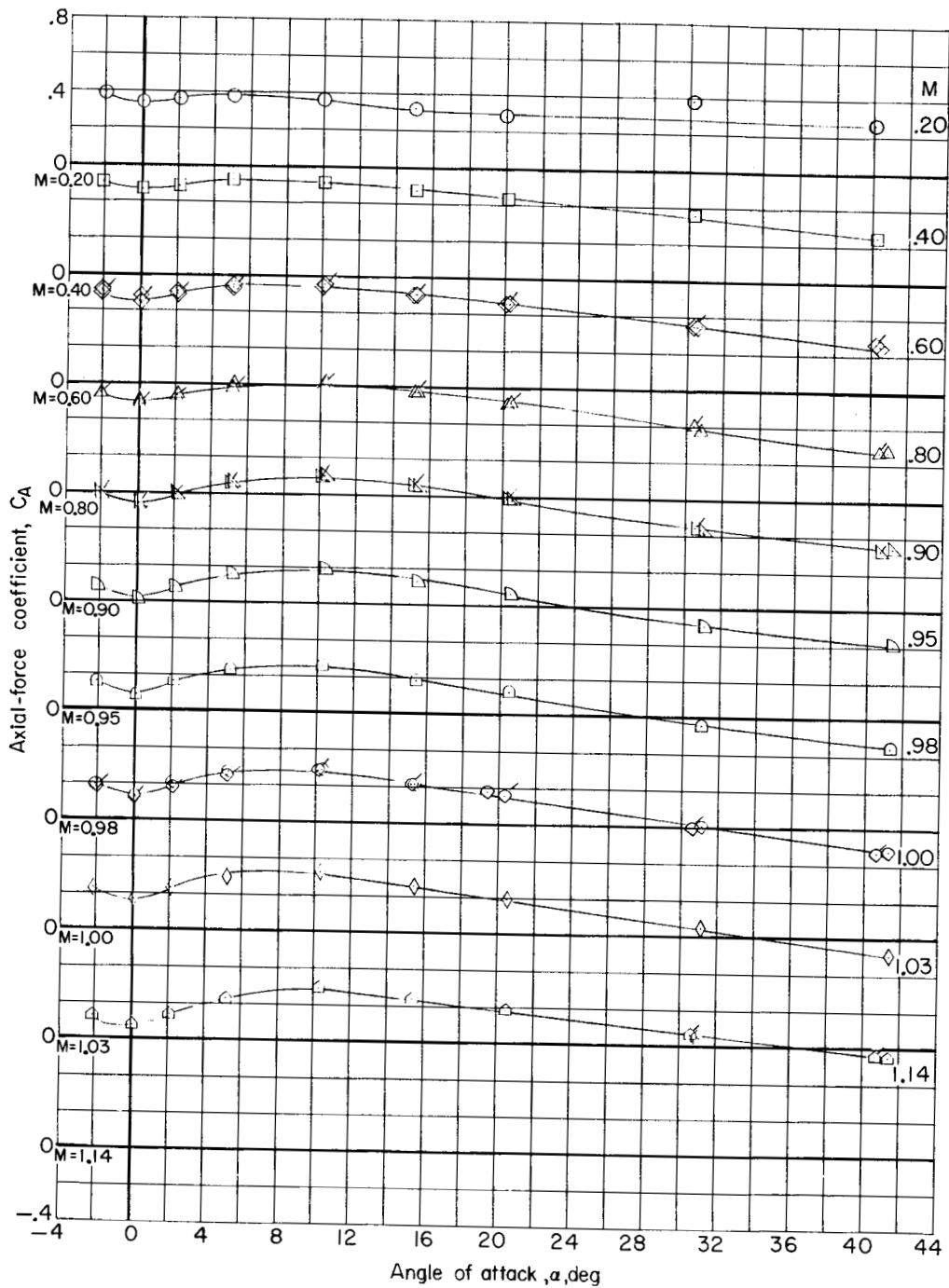
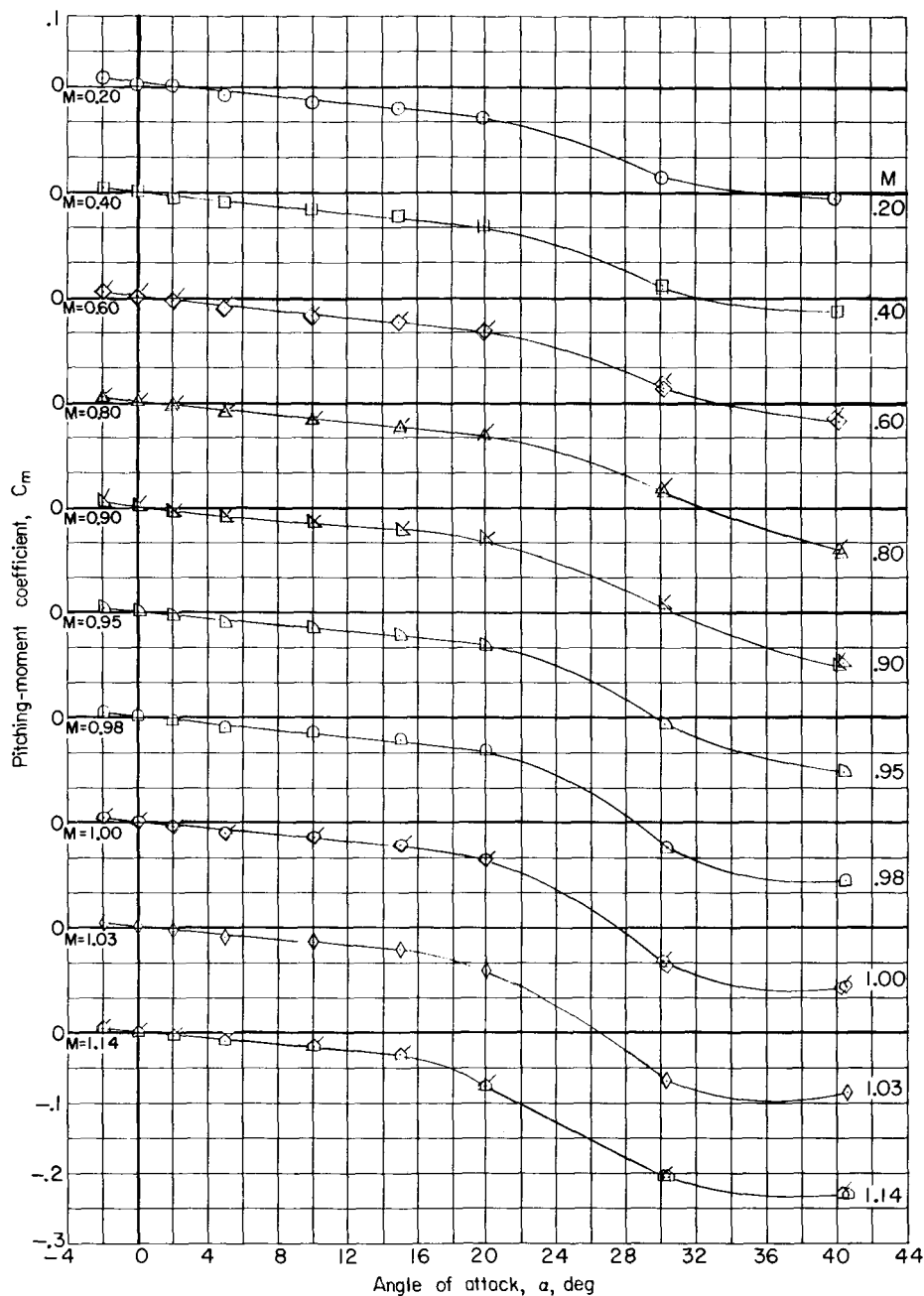
(c) Variation of C_A with α .

Figure 5.- Concluded.



(a) Variation of C_m with α .

Figure 6.- Variation of static aerodynamic characteristics in pitch of model. Reentry configuration. Unflagged symbols denote stagnation pressure of 1.0 atmosphere; flagged symbols denote stagnation pressure of 0.5 atmosphere.

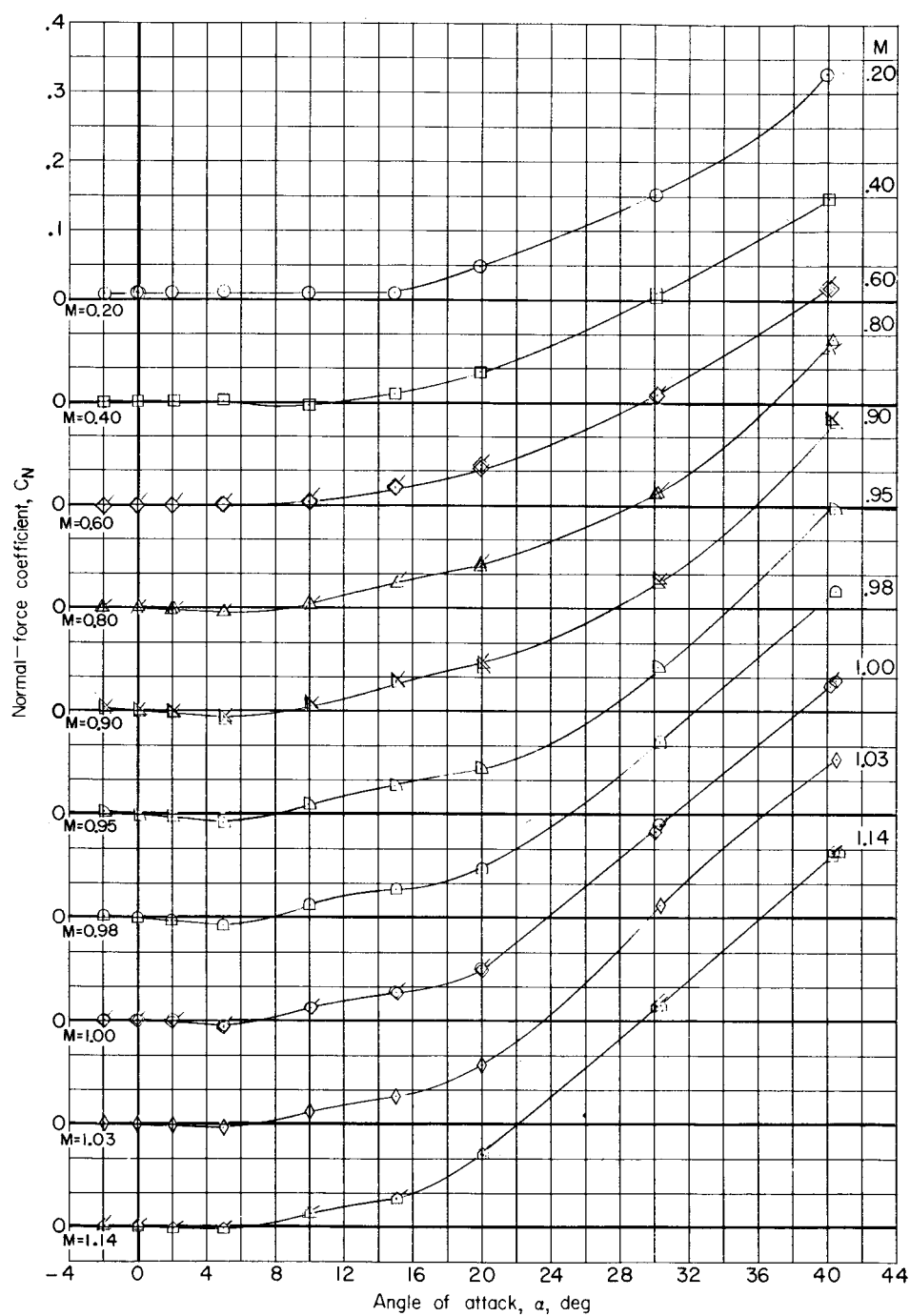
(b) Variation of C_N with α .

Figure 6.- Continued.

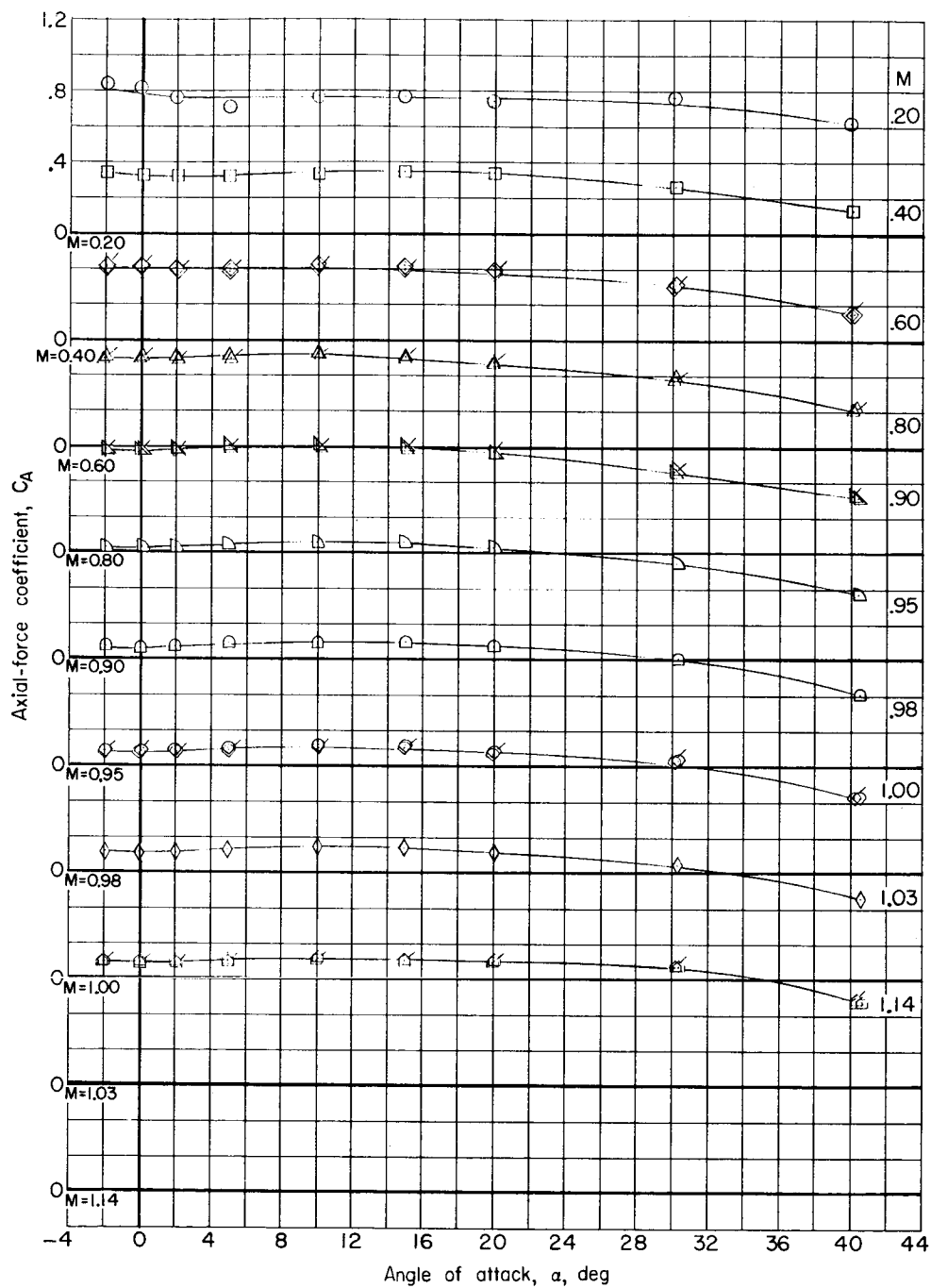
(c) Variation of C_A with α .

Figure 6.- Concluded.

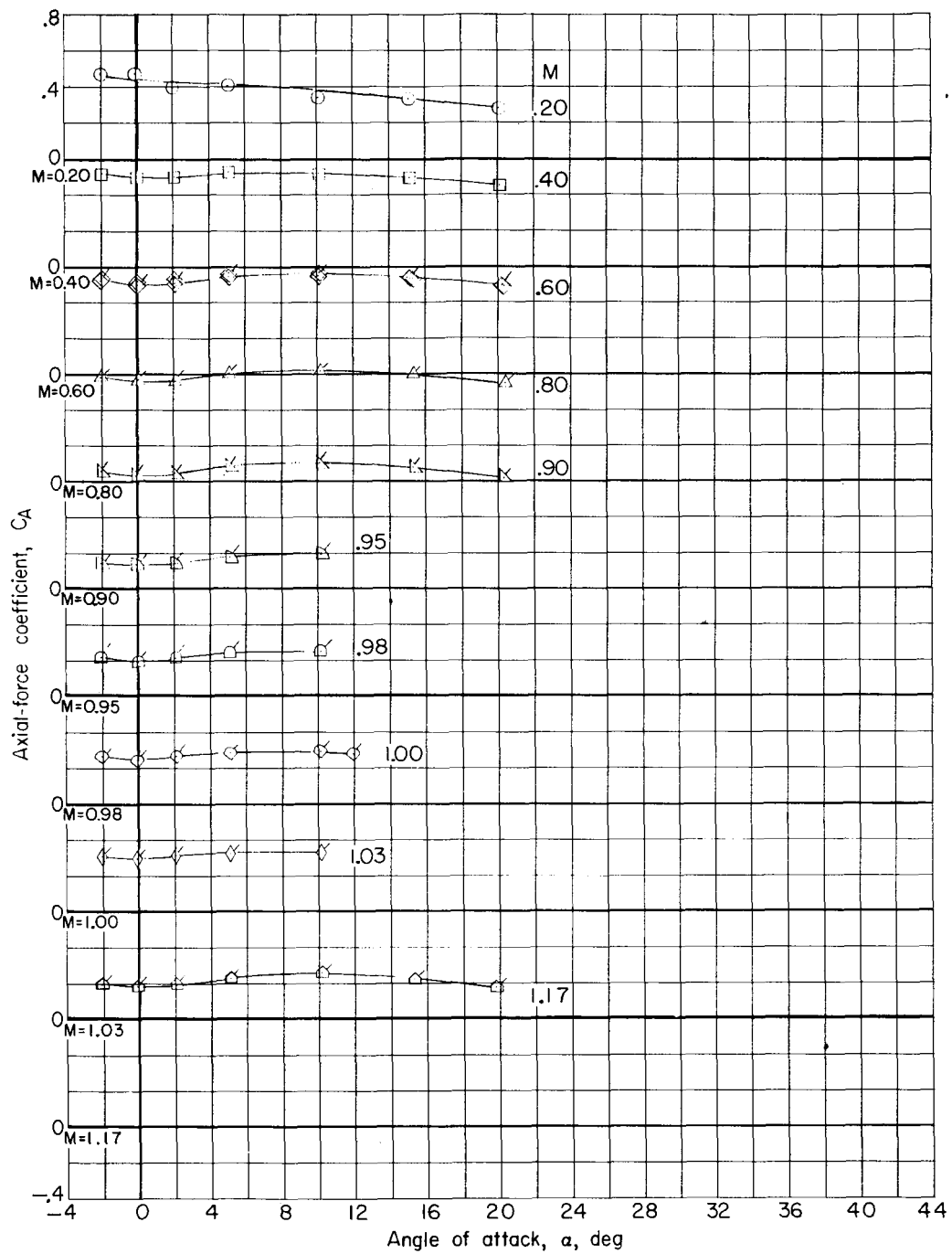
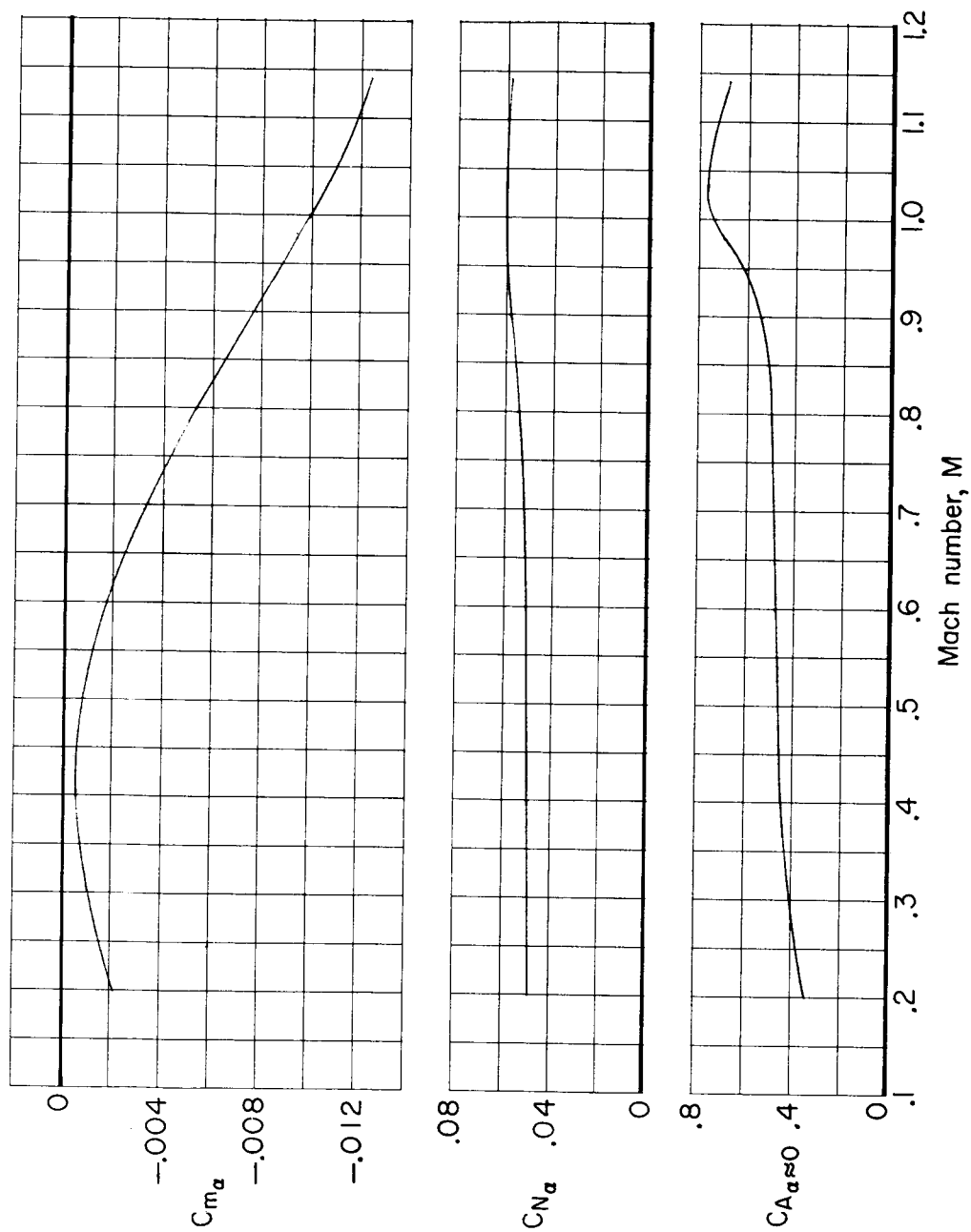
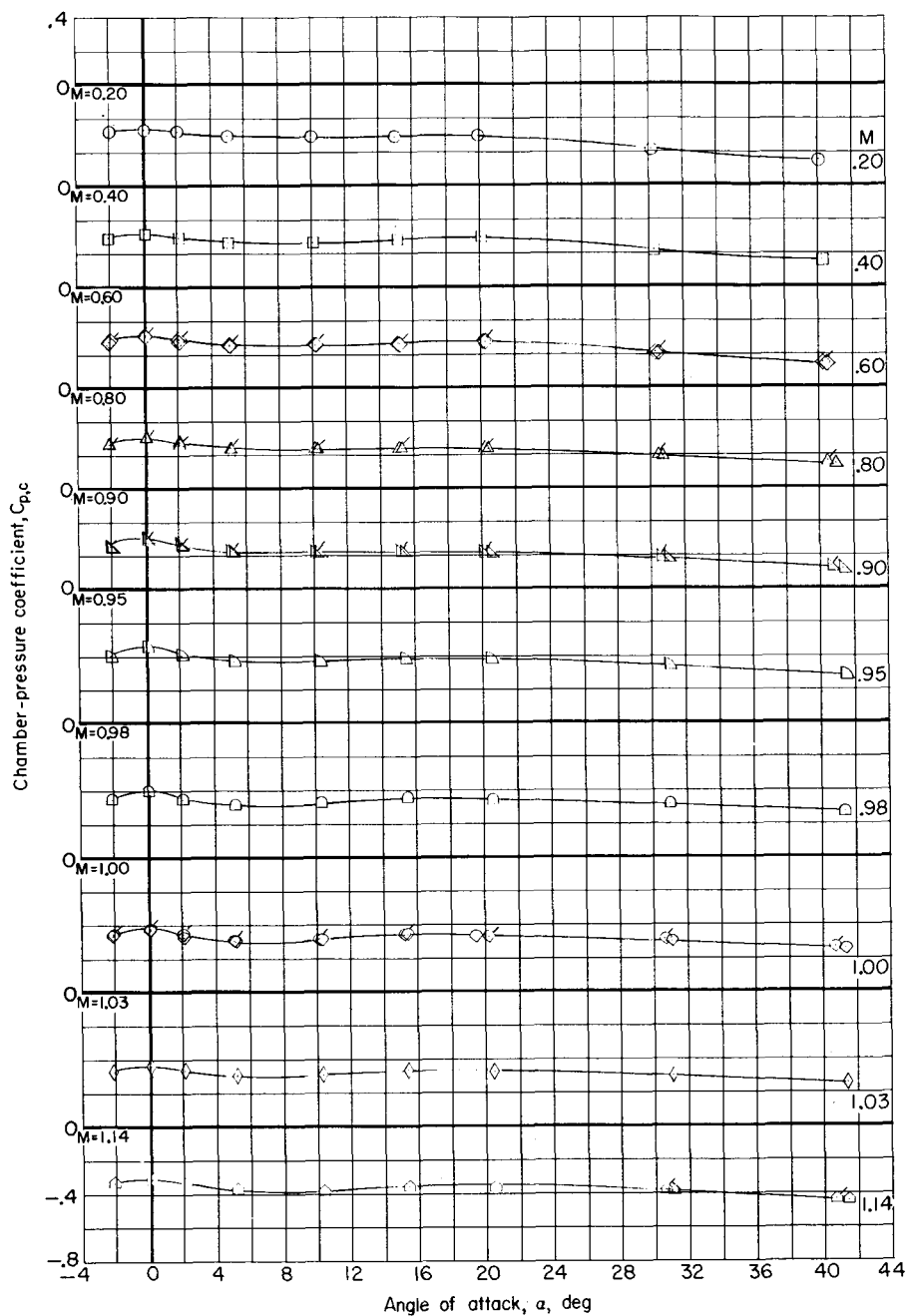
(c) Variation of C_A with α .

Figure 7.- Concluded.



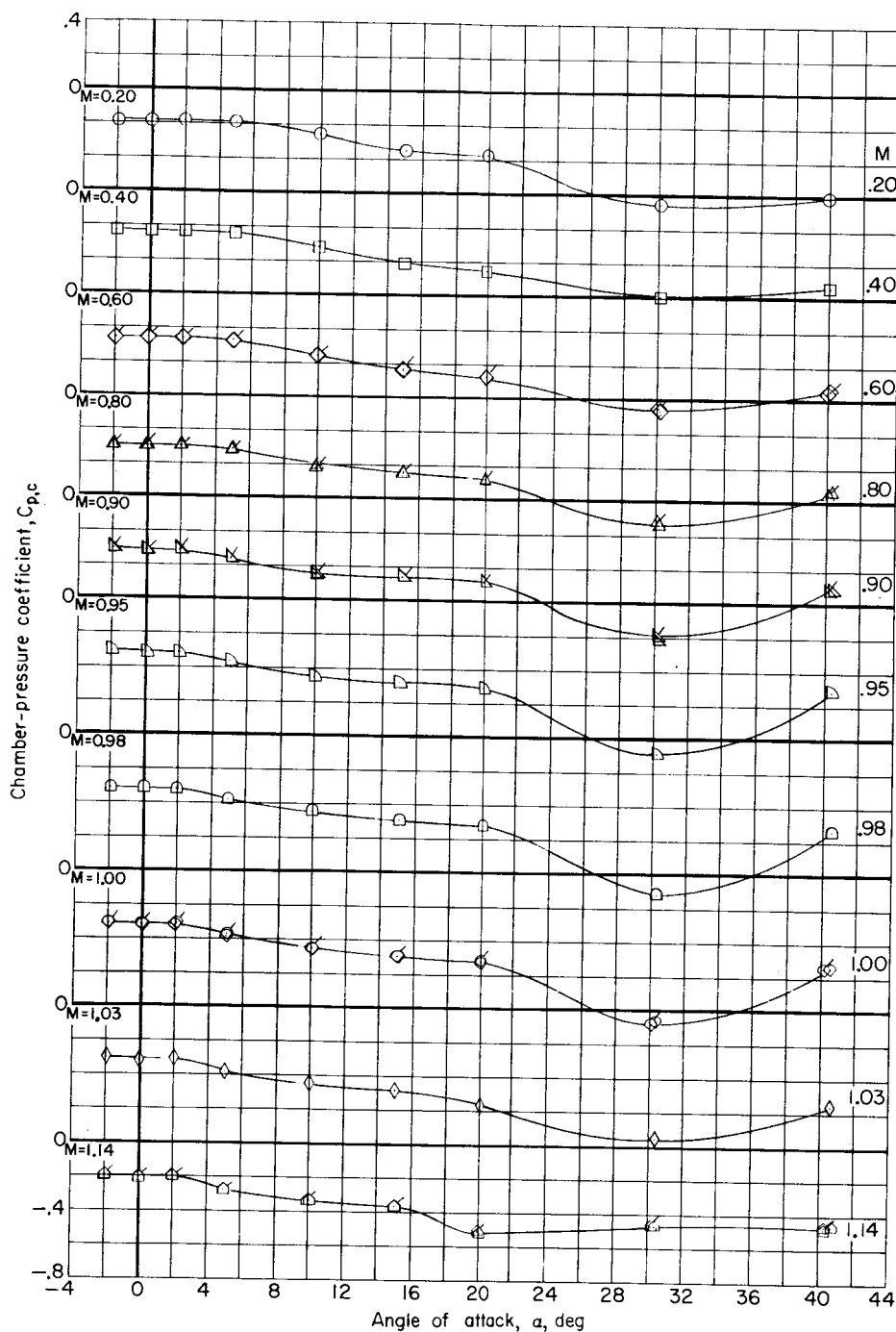
(a) Exit configuration.

Figure 8.- Summary of static aerodynamic characteristics of model.



(a) Exit configuration.

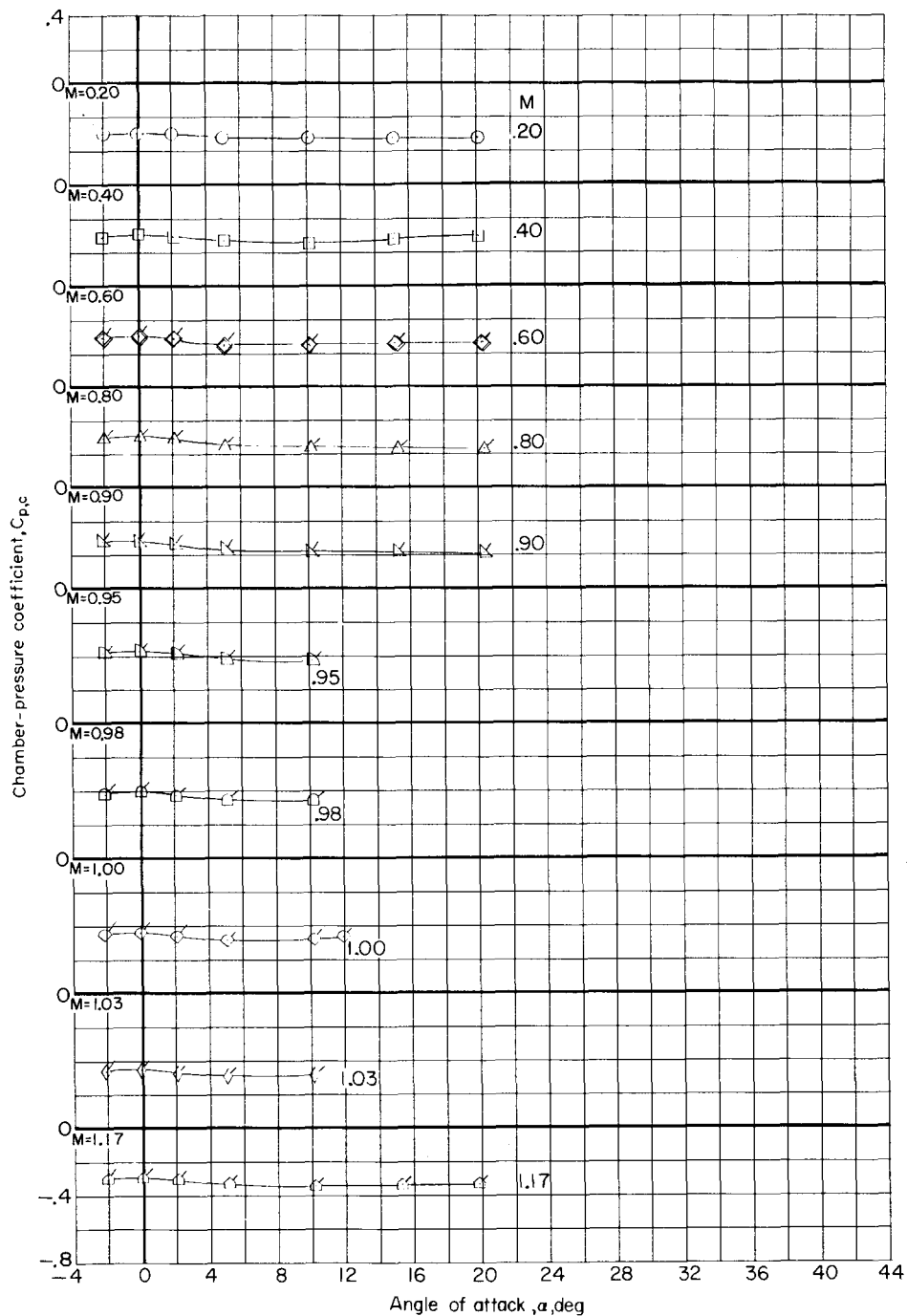
Figure 9.- Variation of model chamber-pressure coefficient with angle of attack. Unflagged symbols denote stagnation pressure of 1.0 atmosphere; flagged symbols denote stagnation pressure of 0.5 atmosphere.



(b) Reentry configuration.

Figure 9.- Continued.

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(c) Escape configuration.

Figure 9.- Concluded.